Forest Sciences

Prince Rupert Forest Region

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Sackungen on a Forested Slope, Kitnayakwa River

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Introduction

Anomalous linear features including uphill-facing (antislope) scarps and troughs trending parallel to slope contours were found on a forested slope adjacent to large bedrock landslides (54° 25' N; 127° 52' W) within the Kitnayakwa River watershed (Figure1). The German term "Sackung" denotes slope sagging, gravitational spreading or deep-seated gravitational slope deformation to describe these linear features in mountainous landscapes. Numerous landslides have occurred in the vicinity over the last 450 years. The sackung features at Kitnayakwa indicate active slope movement and foreshadow another pending landslide.

Physical Setting

Situated in the Hazelton Mountains 45 km east of Terrace B.C., Kitnayakwa River flows north along a fault line to the Zymoetz (Copper) River, which in turn flows into Skeena River (Figure 2). The jagged, glacier-clad peaks of the Howson Range rise abruptly to 3,000 m.a.s.l., east of Kitnayakwa. In contrast, the west slopes are rounded at 1670 m.a.s.l., although deeply incised by streams. Precipitation is in the order of 2,000–2,500 mm per year with 50 to 60 % as snow. Heavy

Figure 1. Sackungen found on the forested slope to left of the large landslide.

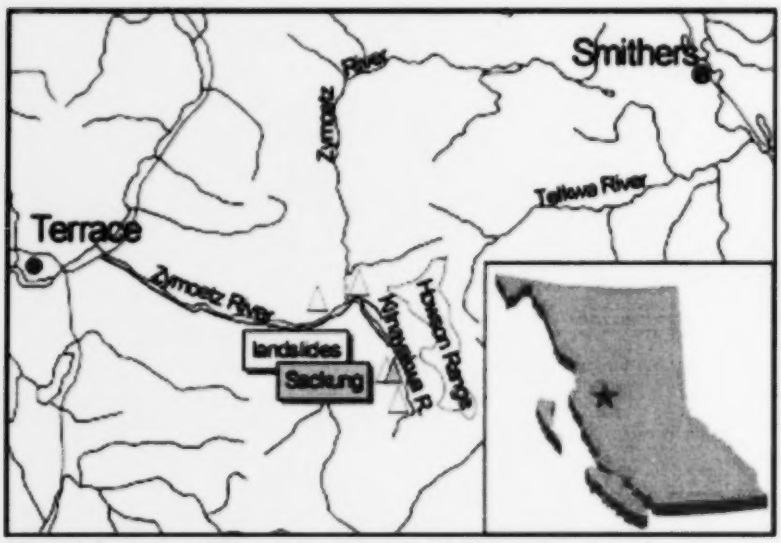


Figure 2. Location of Kitnayakwa River, landslides and sackung features.

snowpacks generally melt by mid-June. Slopes are heavily forested (Coastal Western Hemlock and Mountain Hemlock zones) up to 1,500 m, with continuous tree cover to the top of slopes in the vicinity of the rockslide and sackung features (1260 m).

Bedrock Geology

Bedrock in the study area west of Kitnayakwa River is volcanic. Landslides and sackungen occur between 600 and 1,200 m within the Red Tuff Member of the Nilkitkwa Formation. Characteristically, the Red Tuff Member is well bedded, with fine-grained crystal-lithic tuff making up the majority of the formation (Tipper and Richards, 1976). The colour of the rock ranges from bright red to brick red, with weathered rock generally a darker red. The Red Tuff Member is surrounded and underlain by the harder Telkwa Formation. Overlying the Red Tuff Member at the site is an andesitic rock that is hard and massive in structure. Separation of the red tuff and andesitic rock is along an arching fault line scarp. The weathering rate of the Red Tuff Member is extremely rapid compared to the surrounding and overlying volcanic rocks. This leads to fracturing and crumbling of the bedrock, as seen in Figure 3.

Rockslide Description

Moving an estimated 9.5 M m^3 of rock and surficial material, the largest of the Kitnayakwa slides failed catastrophically 220+ years ago. The scarp of the slide is approximately 300 m high on a slope gradient of 40° (85%). From the top of the head scarp to the end of the deposition zone, the slope is approximately 15° (27%). The length, width, and depth of the failure are 1.9 km, 350 m and 90 m, respectively. The deposition zone of the slide covers approximately 45 ha, forming a hummocky landscape on both sides of the river. A lack of telltale signs of river impoundment, suggests that the river quickly cut through the deposit. The slide appears to have moved very fast judging by the distance travelled and the run-up surface on the opposite side of the valley.

Along the edges of the slide basin and along the headscarp, tension cracks have formed in response to a loss of lateral and vertical support. Two types of tension cracks occur: (1) cracks wider at the top than the bottom are toppling features—side support has been removed and the bedrock is slowly tipping outwards (Figure 4); (2) cracks narrower at the top with a back-sloping top surface are rotational—basal support has been removed and a bedrock

Figure 3. Red Tuff Member, highly fractured and crumbling.

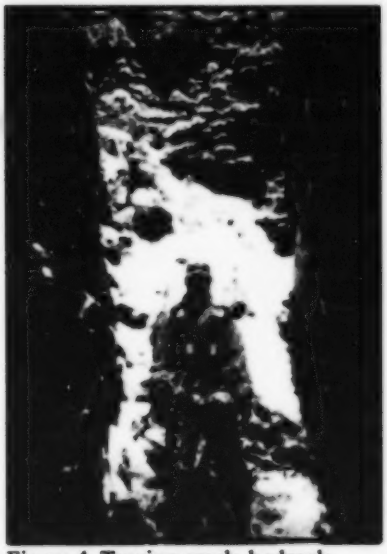


Figure 4. Tension crack, bedrock block is tipping outward.

Figure 5. Tension crack in bedrock, block is sliding out at the base.

block is rotating and sliding out at the base (Figure 5).

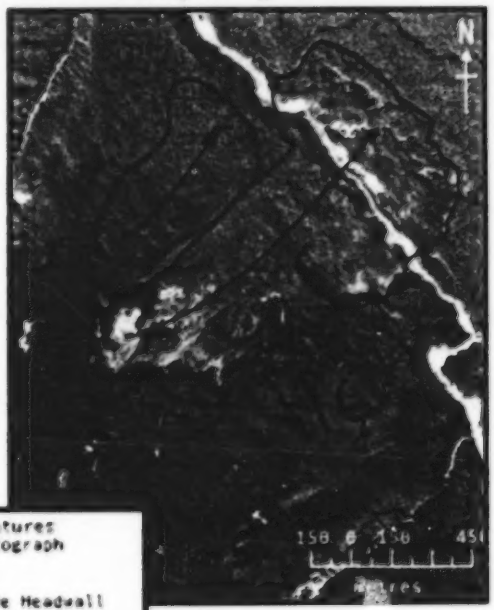
Numerous landslides, all within the Red Tuff Member, are found within 2 km of the large rockslide. Immediately adjacent to the large slide is an intermediate sized rockslide that dates to 460+ years ago. Its headscarp is located along the same fault line within the Red Tuff. A smaller landslide within the debris of the largest rockslide occurred about 50 years ago, possibly a result of river down-cutting through the main landslide debris. Other faces of the slope show signs of movement and smaller rockslides (Figure 6).

Sackung Description

The sackungen at Kitnayakwa create giant steps in the landscape, with moss-covered downslope scarps up to 30 m high dropping down to meet antislope scarps up to 10 m high (Figure 7). The scarps and troughs between scarps trend to roughly parallel slope contours. Antislope scarps range from 18 to 50° (34 and 120%) while the downslope scarps have slope gradients between 17 and 45° (30 and 100%), with most between 24 and 31° (45 and 60%). A distinct fracture line runs along the trough in most features.

Larger sackugen are situated approximately 150 m apart with a trough (depression) up to 25 m wide. Trees are growing in the trough as well as on the steeper ridge crests (Figure 8). Trees growing in the troughs are younger and do not show the extensive signs of movement as found on older trees growing on steeper ridge crests. Scattered between the trees, bedrock rubble and fallen trees litter the width of the troughs. The weathered rock rubble shows little strength and crumbles by hand. Elongate pools of standing water are also found in some troughs, seeping into the fractured rock underneath (Figures 9).

Smaller sackungen in between the larger sackungen are spaced roughly 25 m apart. Trenches are up to seven meters wide and three meters deep, cut across the hillslope at regular intervals.



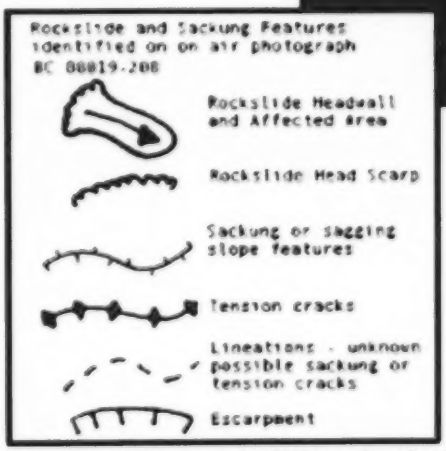


Figure 6. Air photograph of Kitnayakwa landslides and sackung features.

Figure 7. Antislope scarp 10 m high.

Figure 8. Trough, ridge, antislope scarp and downslope scarp.

Figure 9. Elongated pool of standing water as found in some troughs.

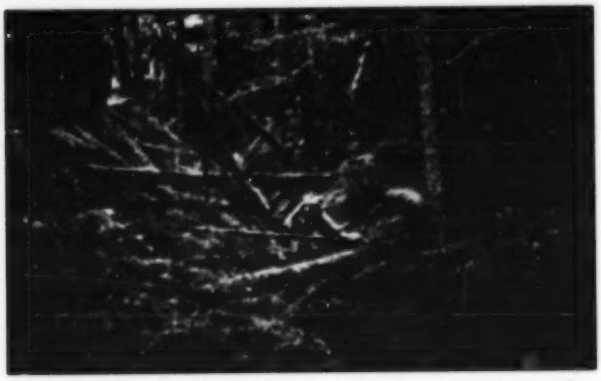


Figure 10. Dead and fallen trees stretching across a trough.

Figure 11. Bowed trees along antislope scarp.

Figure 12. Bowed trees radiating out along a ridge crest.

Vegetation on the smaller, antislope scarps shows signs of movement, and little growth is found at the base of the troughs along the fractures. Dead fallen trees stretch across the troughs, some showing signs of excessive bow prior to falling (Figure 10).

Converging and diverging sackungen are found where troughs meet or separate, creating a maze on the hillslope. Along ridges, bowed trees are leaning both ways in an effort to grow upright (Figures 11 and 12). Split trees and trees with healed cracks occur on some sackungen indicating recent, abrupt movement of the slope (Figure 13).

Directly below the sackung features lies an over-steepened slope. It breaks sharply down to the valley flat. This steep lower slope is not characteristic of the surrounding "U-shaped" glaciated valley terrain and possibly indicates a bulging out of the lower slope.

Figure 13. Split-tree an indication of recent abrupt movement.

The sackung covers an area of approximately 22 ha. Should another catastrophic landslide take place, assuming depths similar to the adjacent rockslide, up to 20 M m^3 of material could move.

Sackung Formation

The formation of sackung features is not well understood; many factors must be taken into account. The foremost factor is bedrock properties. The Red Tuff is a relatively weak rock, heavily fractured and jointed, and it crumbles easily. Water penetrates deep into the Red Tuff through the joints and fractures, resulting in intense weathering at depth within the rock.

Factors thought to directly influence the creation of sackungen are glacial debuttressing, groundwater fluctuations and earthquakes. With melting and retreat of valley glacier ice, the pressure release allows bedrock expansion along joints, fractures and bedding planes, weakening rock strength and creating pathways for water infiltration. Seasonal and climatic cycles of fluctuating groundwater increase and decrease pore pressures within the bedrock, changing shear strength. Earthquake shock could accelerate movement or create stress sufficient to lead to catastrophic movement.

There are two prevailing theories as to how sackung features form. One theory is that sackungen formation is a slow form of rock toppling down the slope. As the rock disintegrates, the joints weaken, and movement on steeper slopes may start. This movement allows the fractured blocks behind it to move, forming the antislope scarps and the sackung type features. This model assumes that the bedrock has a dip normal or near normal to the actual dip of the slope, and does not require a specific failure plane for movement to take place (Figure 14).

The second theory is similar, but assumes that the dip of the rock bedding is roughly parallel to the dip of the slope. As basal support is removed, bedrock blocks can move in sliding and/or rotational motion out towards the newly unsupported area. This leaves the remaining blocks room to slide thus creating upslope-facing scarps and sackung features. A failure surface is assumed within the shifting bedrock; movement would take place along this surface (Figure 15).

Air Photo Recognition of Sackung Features

Air photo recognition of sackung features on a forested slope is very difficult, because many of the features that are associated with sackungen are only visible on the ground. There are, however,

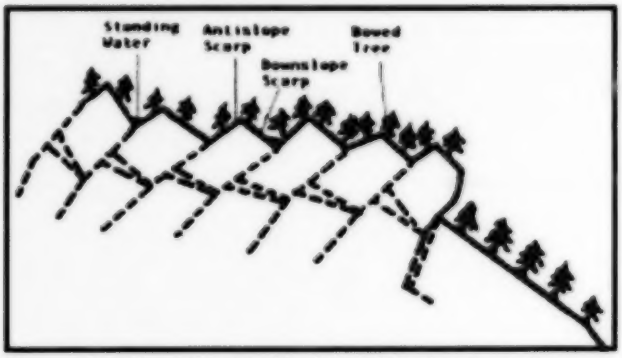


Figure 14. Schematic of bedrock topple and sackung features.

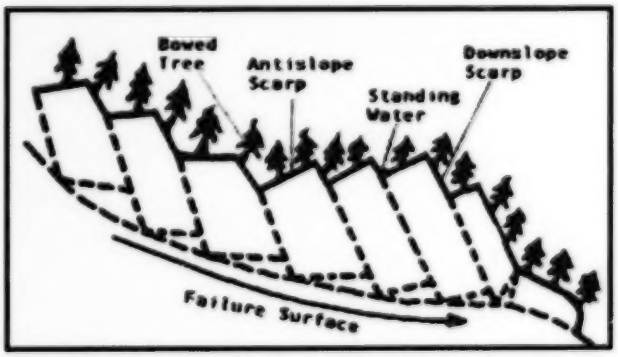


Figure 15. Schematic of bedrock sliding/rotational movement and sackung features.

several larger features that can be seen on air photos (see Figure 6).

❖ Lineations in the forest cover extend parallel to the contours of the slope, differentiating them from streams and small creeks. These lineations are breaks in the forest cover where tree growth has been prevented by the fractures in the ground, or where scarp slopes are too steep for tree growth.

❖ Sharp elevation breaks in the hillslope can also be seen, sometimes accompanied by a rise in elevation at the bottom of the break. These breaks indicate larger sackungen, and the accompanying antislope scarp.

❖ An oversteepened slope at the base of the hill breaks sharply onto the valley flat. No evidence of this type of slope is seen in the surrounding terrain.

❖ A small pond at the base of this slope, also dissimilar from neighbouring slopes.

Conclusion

The sackung features at Kitnayakwa signify an unstable, sagging slope. Another catastrophic failure could occur at any time as a result of past glacial debuttressing and oversteepened slopes, water input through seasonal and climatic cycles, earthquake activity, or a combination of any three. Despite some existing theories sackungen remain enigmatic. To better understand sackung features, researchers must explore climatic and seasonal cyclic effects on ground water, the role of vegetation on hydrology within the contributing basin, the failure process, and bedrock properties.

The sackungen found on the slopes above the Kitnayakwa show evidence of rapid movement in the past and continual ongoing slow movement. This persistent instability poses the question: should human activities, such as logging and road construction, take place on these slopes?

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Suggested Reading

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